Vacuum Packaging of Home Furnishings—Case Study on Blankets

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Abstract

The vacuum packaging of blankets has been studied to reduce the bulk of blanket. The applicability to practical use is also discussed.

Following results are obtained:

- (1) To reduce the bulk of blankets by vacuum packaging, it is necessary to regulate pre-conditioning by heat drying (without increase in the level of segmental mobility in fibers). To reduce the moisture content of blanket, acrylic blanket should be dried for 40 minutes and wool blanket for 120 minutes at 58–60°C.
- (2) The compacting pressure should be determined by considering reduction ratio, kind of fibers, fabric weave of blanket. Furthermore, the recovering ability of creases and bulk of blanket after unpacking should be also considered.
- (3) After vacuum-packaging of blanket, it is recommendable to store blanket at the low temperature: –2–0°C. Especially, acrylic blanket recovers its thickness and crease quickly after unpacking.
- (4) The questionnaire survey shows that vacuum-packed wool blanket is expected to recover its creases and bulk in a short time of 24 hours by unpacking after 6-month storage at 10–30°C. On the contrary, vacuum-packed acrylic blanket has some problems in creases recovery after unpacking.

1. Introduction

Because of increase of delivery cost, we cannot reduce the cost of textile products. Therefore, cost reduction can't be accomplished with the only rationalization of the production.

Transforming and storing costs of textile products greatly depend on the space of volume which their products occupy. Especially, home furnishings like bulky textile products greatly cost a great deal in comparison with any other apparels and textile products.

If the compactly packaging methods of textile products is applied by means of transforming and storage, high efficiency and rationalization of the delivery will be expected. Especially, the effect on the compacting blanket is remarkably expected.

With the conventional compacting method such as earlier bulk-reducing packaging method by the uncontrolled processing has had unacceptable problems such as crease and flattening. Therefore, it has been necessary to use post-treatment in order to improve bulk and crease of blanket products. Recently, the volume reducing method of textile products by vacuum packaging is developed and gradually begins to be applied to the package of comforters and apparel products in foreign countries^{[1]–[3]} as well as Japan^[4].

However, this vacuum packaging method has not yet been applied in Senshu area where 96% of all blankets in Japan have been produced.

The technical merits of blanket articles are shown as follows:

- (1) To reduce transporting cost of the textile products in delivery.
- (2) To reduce the storehouse space and to prepare blanket products for disaster by large quantity storage.
- (3) Compacting storage of textile products in domestic life.
- (4) The vacuum-packed textile products is useful to prevent from insect, mold.
- (5) The vacuum-packed textile products can be useful to

prevent from moisture, vapor and aqua.

Therefore, we took a notice of it and studied on the use of bulk-reducing by vacuum packaging of blanket. The expected problems by compacting blanket are given as follows:

- 1) Packaging method of blanket products.
- 2) The selection of packaging or wrapping material like film^[5].
- 3) Pre-conditioning before vacuum packaging of blankets.
- 4) Storage condition, storage term and the recovering ability after unpacking.
- 5) Compressive pressure of vacuum packaging and the recovering ability after unpacking.
- 6) The effect on feeling and physical properties of blanket products.

We studied on the problems of 3), 4), 5), 6) with wool and acrylic blankets. However, comments of essential property and surperior wrapping film for packaging material is mentioned on the selection of packaging material of 2). And with the pre-conditioning of 3), the explanation on microwave drying method is mentioned in result and consideration.

Fig. 1 Experimental vacuum packaging equipment

2. Packaging Materials (Film) and Selections

2.1 Essential properties of packaging film^[5]

The layer-film with many functions comes to be recently very popular as the packaging material. Table 1^[5] shows the functions which are demanded for layer-film. The essential properties as packaging film for home furnishings are gas barrierability, heat-seal, mechanical properties and transparency etc. Now we explain the film material with superior properties.

2.2 Superior properties as packing film

2.2.1 Barrierability of film

(a) The representative films with oxygen gas-barrierability are made of polyester, nylon, polyacrylnitril, Pvdc and EVA saponification.

(b) Polyolephyne film shows the superior moisture vapor barrierability. Especially HDPE has superior barrierability by elongation and press-processing.

The layer-film with oxygen and moisture vapor barrierability is basic packaging material for home furnishings. tables 1, 2

(Table 2^[6] shows gas permeability and moisture vapor transmission to various films.)

2.2.2 Heat-seal property of film

As the layer-film is used as sealing-package material, the heat-seal is one of the most important properties. Thermoplastic resin shave fundamentally heat-seal property. Polyolephyne plastis-film has superior heat-seal property, (EVA, LDPE, Ionmer, non-elongation P.P. and especially EVA has two types of low and high temperature heat-seal properties.) For the packaging of home furnishings, LDPE and HDPE have the low cost performance.

2.2.3 Mechanical properties of film

As packaging materials needs to protect the articles in package, it is very important to have the following properties as packaging material; tensile, shock and stab strength, stiffness, pinhole resistance etc. Nylon is adopted as the superior plastic having excellent properties such as tensile, shock, stab strength etc.

Though nylon is applied to the packaging material for the refrigeration foods, it is also the most appropriate packaging material for home furnishing to protect the articles in package under storage and transportation. P.P. plastic is also useful as

Name of films	Gas permeability A), B) (cc/m ² -24 hr-atm/25 μm)			Moisture vapor transmission C) (g/m ² -24 hr/25 μm) 40°C-90% RH
	Carbonate gas	N gas	O gas	
LDPE	42,500	2,800	7,900	24-28
HDPE	9,100	660	2,900	22
non-elongation PE	12,600	760	3,800	22-34
2 axis-elongation P.P	8,500	315	2,500	3-5
PVdc-coat				
2 axis-elongation P.P	8-80	8-30	<16	5
nomal cellophan	6-90	8-25	3-80	<720
PVdc coat cellophan	—	—	15*	<12
Polyester	240-400	11-16	95-130	20-24
non-elongation nylon	160-190	14	40	240-360
2 axis-elongation nylon	—	—	30*	90
PVdc-coat 2 axis-elongation	—	—	10*	4-6
Polystyrene	14,000	880	5,500	110-160
Polycarbonate	17,000	790	4,700	170
Poly-vinyl-chloride	320-790	30-80	80-320	5-6
Vdc-VC-copolymer	60-700	2-23	10-110	3-6
EVA saponification	—	—	2*	30
PVdc-coat 2 axis-elongation PVA	—	—	3*	4
m-xylene azide	—	—	4*	23
Polyacrylnitril	—	—	3*	20

Coments: A) The value of PVdc coat is differ to type, quantity of tile coat materials.
B) The measurement condition and method of gas permeability,
no mark: 25°C-50% RH, ASTM D 1434-66
mark: 27°C-65% RH, same pressure oxygen-electrolyte method
C) Gas permeability and moisture vapor transmission shows the value exchanged in thickness 25 μm.

Table 3 The superior properties as packaging film-materials

●: very good; ○: good

	P.E.T	Nylon	PVdc	Polyacrylnitrile	EVA	HDPE	LDPE	P.P.
Oxygen barrier ability	○	●	●	●	●			
Moisture vapor barrier ability				○	○	●	○	○
Ability to heat-seal of film					○	●	●	●
Mechanical property		●						○*
The transparency to articles	○	○						
Film cost						●	●	

*P.P. (poly-propylen) is no good for cold-shock.

P.E.T: Polyester, HDPE High density polyethylene, PVdc: Poly-vinyle-chloride, LDPE: Low density polyethylene, EVA: Ethylene-acetate vinyl copolymer saponification

the packaging material but it is not always good at shock strength at the low temperature.

2.2.4 Transparency of film

Transparency is very important property to enhance the value of articles in packaging. Nylon and polyester are materials with the excellent transparency.

As textile articles are especially tinted with color and pattern, nylon and polyester are recommendable to be applied to packing materials in order to select textile articles. The comparative abilities of representative film with superior essential properties are shown in Table 3.

It is recommendable to use polyethylene/nylon layer-films as the most appropriate packaging materials for the vacuum packaging of home furnishings from the point of view in selection of packaging film.

3. Method of Experiment

3.1 Sample and selection of packing film

Wool and acrylic blankets which were conditioned in the atmosphere at 20°C-65% RH were used as the experimental samples. Blanket types are raised-weave, piled-tufting, piled-mayer, piled-boa. However, practical size and sample size blankets were used in response to the contents of experiments. Packaging materials applying the layer-film of which thickness of polyethylene/nylon was 55 µm/45 µm for the vacuum packaging. And this film has the properties in which gas permeability and moisture vapor transmission ability are very low in long-term storage (for about 5 years).

3.2 Pre-conditioning and reducing the moisture content of fiber by heat drying

The equipment for pre-conditioning: the circular-heating apparatus.

Heat drying temperature: 58–60°C

Weight (W_1) of the blanket is acquired by heat drying. The reducing ratio of the moisture content in fibers were calculated by difference from weight (W_0) of that before heat drying.

The reducing ratio of the moisture content is indicated in the following calculations:

$$\text{Reducing ratio} = (W_0 - W_1) / W_0 \times 100 (\%)$$

3.3 The vacuum packaging method and storage of the vacuum-packed blanket

The textile blanket articles were packed by the vacuum-packaging system which produced by way of trial in our Institute.

Packaging compression: vacuum-packed at about -600 mmHg (0.816 kgf/cm²).

Storage condition: stored in the atmosphere at (20°C-65%) and (-2°-0°C)

3.4 Recovery after unpacking of vacuum-packed blanket

The vacuum-packed blanket that stored for a period in a storage condition was evaluated after unpacking. The recovery of reduced bulk of vacuum-packed blankets were shown by the strain ratio of the bulk thickness (h_1) after unpacking to the native bulk thickness (h_0) before packaging.

The strain ratio of reduced bulk is indicated in following equations:

$$\text{Strain ratio} = (1 - h_1/h_0) \times 100 (\%)$$

The remained creases after unpacking was shown in Table 4 compared with the native blanket before packaging in visual-evaluation, that is, the rank consists of following signs:

“Good”, “-” shows “recovered” and “★” shows “remains creases” and “☆” shows “remains a little creases”.

3.5 Bulk reduction and stress relaxation by compression

Compressive load in a package of vacuum-packed blanket is loaded by an difference between the atmospheric pressure and the vacuum pressure in a package.

And so bulk reduction ratio of blanket was studied on the vacuum packaging method. Furthermore, bulk reduction ratio and variation ratio of compression were considered by compressive load corresponding with vacuum pressure which was measured by a testing apparatus applied “Instron”. Bulk reduction ratio is shown by a fraction or a decimal of the compressed bulk thickness (h_1) after packaging to the bulk thickness (h_0) before packaging.

Variation ratio of compression is shown (w_1/h_2), that is, by the compressive load ratio (w_1) by constant compression to variation ratio of the bulk thickness (h_2) of the compressed blanket.

Stress relaxation of blanket by compression is studied by compression loads which was measured by a testing apparatus applied “Instron”.

And the recovering ability of bulk of blanket after unpacking is forecasted from the stress relaxation time of blanket by compression.

Blanket samples folded in 4 layers, and of which was 5 cm×5 cm in size were used in this experiment.

4. Results and Consideration

4.1 The vacuum-packed and the press-packed blankets

The native blanket before and after packaging and the packed in types were shown in Fig. 2. The opened-blanket was shown in back and the folded blanket in 18 foldings at the left

Table 4 The recovering ability of crease and bulk of the packed blanket after unpacking

(Pre-conditionitig)		The vacuum-packed:		60°C-2 hr heat drying			
		The press-packed:		20°C-65%			
(Storage terms):				7 days			
(Recovery condition):				20°C-65%RH			
(Compressive pressure):				-600 mmHg			
Treat	Blanket-type	soon	30 min	1 hr	24 hr	4 days	10 days later
vacuum	raised acrylic 125 mm, 1/3.2 16 folding	80mm	125mm	good	—	—	—
		★	★	★	☆	no	—
press	raised acrylic 140 mm, 1/3.0 16 folding	95	115	115	125	130	130
		★	★	★	★	★	☆
vacuum	raised wool 125mm, 1/3.8 18 folding	70	125	good	—	—	—
		★	☆	no	—	—	—
press	raised wool 125mm, 1/3.8 18 folding	70	100	100	105	110	110
		★	★	★	★	★	☆

Good, —: recovered, ★: Remain creases, ☆: remain a little creases, Blanket type []: Thickness of 16 or 18 thicknesses of blanket. Bulk reduction ratio, Thicknesses of blanket

- (1) The native blanket
- (2) The vacuum-packed blanket after pre-conditioned (2 hr heat drying at 60°C)
- (3) The press-packed blanket after pre conditioned (24 hr at 0°C-65%)

Fig. 2 Photos of the native blinket, the vacuum-packed and the press-packed blanket

- (Pre-conditioning) The vacuum-packed: 60°C-2 hr heat drying
The press-packed: 20°C-65%
- (Storage term): 7 days
- (Recovery condition): 20°C-65%
- (Compressive pressure): -600 mmHg

Fig. 3 The recovering ability of creases and bulk of the packed raised-blanket after unpacking

side and the vacuum-packed blanket in the center and the press-packed blanket at the right side. The vacuum-packed blanket was pre-conditioned under 60°C-2 hr by heat drying and the press-packed blanket was regulated at 20°C-65% without heat drying.

Bulk reduction ratio of the vacuum-packed blanket and the press-packed blanket were about 1/3.8 in comparison with the native blanket before packaging.

4.2 Effect by pre-conditioning

Table 4 and Fig. 3 shows the recovering ability of bulk and creases of the vacuum-packed blanket and the press-packed blanket which was unpacked after 7 days storage term. Tested blankets were the raised-blankets made of wool and acrylic. It took for 30 min to recover the reduced bulk of the vacuum-packed blanket to the state of the native blanket before packaging.

And it took for 4 days in acrylic blanket and for one hour in wool blanket to disappear creases of blanket.

On the contrary, it isn't easy to recover the reduced bulk and to disappear creases of the press-packed blanket to the native blanket before packaging.

Bulk and creases of the packed wool blanket in 1 hr later after unpacking was shown in Fig. 4. After unpacking in Fig. 4, bulk of the press-packed blanket doesn't recover to the native state and creases of that remains.

This is the case that the moisture content is accumulated in fibers of the blankets.

4.3 Heat drying time for pre-conditioning

To reduce the moisture content of blanket in package, it is necessary to do re-conditioning before packaging. In order to reduce the moisture content of fibers, it must have been drying at low temperature^[9] and in short time without an increase in the level of segmental mobility in fibers.

Reduction ratio of the moisture content with 7 types of wool and acrylic blanket were shown in Fig. 5 at 58–60°C by heat drying. Acrylic blankets in 3 types became in equilibrium about 40 min, wool blankets in 4 types about 100–120 min^[7] and the moisture content was not be able to reduced anymore.

Therefore, to reduce the moisture content of blanket at

Fig. 4 Photo of the native blanket and those of creases and bulk of the vacuum-packed-blanket, the presspacked blanket after unpacking

*blanket weight before heat drying

Fig. 5 Reducing ratio of the moisture content by heat drying (Heat temperature: 58°–60°C)

drying temperature of 58–60°C acrylic blanket should be dried for 40 min and wool blanket for 2 hours.

4.4 Moisture content by the microwave heating method

Heat drying method wasn't effective for energy cost.

And so with pre-conditioning of home furnishings totally, microwave heat drying was more effective than that of conventional heat drying. Therefore, it will be expected as the effective drying method in the future.

Microwave heating method can efficiently extract the remained the moisture content from the surface of product which was previously evaporated by a conventional hot air system. An example was shown in Fig. 6^[8].

As shown in Fig. 6, conventional heating provides adequate evaporation and moisture migration at the higher moisture level.

When the microwave heat drying method applied to dry, the moisture remained below 25% level, drying time can be

Fig. 6 Ratio of the moisture content by heat drying method

Sample No. 1–3: raised-blanket
Sample No. 4–6: piled-blanket

Fig. 7 Bulk reduction-compression curves of various blankets by compressive load

remarkably shortened. If microwave heat is used for drying of blanket in the future, drying time will be shortened within 15–20 min for the blanket, type (140 × 200 cm in size and 1.32–2.50 kg in weight) made of wool.

Moisture content of acrylic is far lower than wool, in the case of acrylic blanket drying time is shorter than that of wool. However, we limited to the preliminarily experiment in this paper.

4.5 Bulk reduction curves by press-load

In order to reduce bulk of blanket by vacuum packaging, the most appropriate bulk reduction ratio and vacuum compression was studied. Fig. 7 shows bulk reduction curves by some press-loaded blankets.

Fig. 8 Bulk reduction and compression ratio of the raised blankets by mechanical compressive conditions

Fig. 9 Bulk reduction and compressive ratio of the piled blankets by mechanical compressive conditions

As shown in Fig. 7, it is classified in 2 types curves of the raised-blanket and the piled-blankets. The blanket type is shown by the curves in Fig. 7.

The more press-load increase causes to reduce the bulk of raised-blanket, the more bulk reduction variation occurs by gradual decrease of compression. It is shown that the bulk reduction effect by compression is small in the higher press-load level. On the contrary, bulk reduction variation of the piled-blankets by compression is rapidly raised in lower press-load level.

And the piled-blankets indicates same curve-lines as the raised-blankets. From these results, the compacting pressure should set in order to get the best recovering ability of reduced

bulk by applying raw material and appropriate structure of blanket.

4.6 The most appropriate compression for blanket

Bulk reduction ratio and compressive variation ratio with press-loads was studied to get the most appropriate compressive condition of blanket. Bulk reduction ratio and compressive variation ratio diagrams of blankets were shown in Figs. 8, 9. However, compressive variation ratio is indicated by the press-loaded to the compressive variation and as a reciprocal of the values which was calculated by the compressive variation to the increased of constant press-loaded (50 mmHg-0.068 kgf/cm²). This ratio is indicated as following formula and dimensions;

$$\frac{\text{the press-loaded}}{\text{the compressive variation}} = \frac{[\text{kgf/cm}^2]}{[\text{cm}]} = \left[\frac{\text{kgf}}{\text{cm}^3} \right]$$

that is, this means load per volume unit and shows that the lower the ratio becomes, the smaller a load by compression becomes.

As I mentioned above, from the result and consideration, the following points are recommendable to set the most appropriate compression for vacuum packaging;

To recover bulk of blanket to the native state within 24 hr after 60 days, or longer storage of the vacuum packaging blankets made of wool materials, wool-blanket should be determined in following conditions; Raised-blanket should be guage pressure below -450 mmHg and reduction ratio of 1/3-1/3.5 to the native state or compressive variation ratio below 0.272.

Piled-blanket should be below -400 mmHg and 1/6 or not any more and below 0.272.

On the contrary, in order to recover bulk of blanket to the native state within 3 days after 60 days or any more storage by means of the vacuum packaging blankets in acrylic materials, acrylic-blanket should be set at the following conditions;

Raised-blanket should be set at the pressure below -450 mmHg and reduction ratio of thickness below 1/3 to the native state or compressive variation ratio below 0.272.

Piled-blanket should be set at the pressure below -400 mmHg and reduction ratio of thickness 1/5-1/6 or below 0.272. Then, the bulk of blanket will be expected to recover effectively to the native state.

4.7 Stress relaxation time of blankets by compression

The vacuum-packed blanket means that compressive pressure is loaded to the blanket in the package until its unpacking. The recovering ability of bulk of blanket after its unpacking is mainly influenced by the condition of the previous processing as well as the storage concerning with the moisture content and the temperature. The recovering ability of bulk of blanket shows the dependency on the required time to recover its original bulk state after unpacking at 20°C-65% RH.

In this case, the higher the pressure in the package becomes, the bigger press-load to the blanket in the package becomes. This means that it takes a long time to recover the bulk of blanket after unpacking. And so we studied on the recovering ability of bulk by different compressions caused by vacuum packing for long-term.

Stress relaxation curves of the raised-blanket as well as the piled-blanket are shown in Figs. 10, 11.

The blankets in two types are reducing compression in

Fig. 10 Stress relaxation curves of the raised blanket under the different mechanical compressive conditions

Fig. 11 Stress relaxation curves of the piled blanket under tile different mechanical compression conditions

lenient curves except different, sudden reduction of compression curves in initial state.

And so relaxation times of blanket by the different compressive loads were calculated in following method; relaxation time ($1/e = 36.79\%$ of initial compression) was taken from the graph (Fig. 11) of the extrapolative method indicated by logarithm of time in horizontal axis shown in Fig. 12. In the same way, the relaxation times of blanket articles were taken and these values are shown in Table 5. With the recovering ability of blanket after unpacking in the case of a constant vacuum pressure, it is realized that relaxation time of blanket has something to do with the limitation of storage-term on the capable recovery to the native state. Relaxation time by compression is long in the case of the smaller compression pressure in package with two types blankets.

It is suggested in the following points;

(t: to become $1/e$ of initial compression)
Horizontal axis: (n) in logarithm value of time
 $T \text{ (sec)} = n \times \exp(a \times 10)$

Fig. 12 Stress relaxation time of the raised blanket made of wool under the different mechanical compressive conditions

Table 5 Compressive relaxation time various blankets under different compressions

Blanket type	Compressive load (pressure)	
Raised blanket (wool)	0.614 kgf/cm ² (-452 mmHg)	0.850kgf/cm ² (-625 mmHg)
Relaxation time T(rw)	$2.8 \times 10^8 \text{ sec}$	$1.78 \times 10^8 \text{ sec}$
Raised blanket (acrylic)	0.626 (-460)	0.775 (-570)
T(ra)	$10 \times 10^4 \text{ sec}$	$8.3 \times 10^4 \text{ sec}$
Piled blanket (wool boa)	0.632 (-465)	0.829(-609)
T(pkW)	$15.8 \times 10^7 \text{ sec}$	$3.3 \times 10^7 \text{ sec}$
Piled blanket (acrylic mayer)	0.612 (-450)	0.840 (-617)
T(pam)	$3.16 \times 10^5 \text{ sec}$	$2.4 \times 10^5 \text{ sec}$
Piled blanket (acrylic tuft)	0.628 (-469)	0.832 (-612)
T(pat)	$5.2 \times 10^6 \text{ sec}$	$8.3 \times 10^5 \text{ sec}$

T: to be $1/e$ of the initial stress;
T (): () is an abbreviation with type and materials of the blanket.

In the case where storage time of the vacuum-packed blanket is within compression relaxation time, the recovering time of bulk after unpacking is short at the smaller compressive load, and the recovering ability of blanket is better than that of larger compressive load. The relaxation times of acrylic blankets (raised fabric, mayer, tufting) are short in comparison with that of wool blanket. It shows the necessity of the following setting of compressive load: the elastic recovery by compression with acrylic material is lower than that of wool material and the recovering ability of acrylic blanket is inferior to wool blanket.

Therefore, the compacting pressure should be determined to set by considering the kind or fiber type of blanket.

Table 6 The recovering ability of creases and bulk of vacuum-packed blanket after unpacking
 (Pre-conditioning): 60°C-2 hr heat drying
 (Storage terms); 50-60days
 (Recovery condition); 20°C-65%RH
 (Compressive pressure) -600 mmHg

Blanket-type	soon	30 min	1 hr	24 hr	3 days	10days later
raised acrylic 145 mm, 1/3.2	78mm	130mm	133mm	142mm	145mm	good
16 folding	★	★	★	★	★	☆
raised wool A 126 mm, 1/3.8	68	110	126	good	—	—
18 folding	★	★	no	—	—	—
raised wool B 125 mm, 1/3.6	60	105	125	good	—	—
18 folding	★	★	no	—	—	—
piled wool 200 mm, 1/5.3	113	190	197	200	—	—
12 folding	★	★	☆	no	—	—

Good, —: recovered, ★: Remain creases, ☆: Remain a little creases, Blanket type []: thickness of 16 or 18 thicknesses of blanket. Bulk reduction ratio, Thicknesses of blanket

Fig. 13 The recovering ability of creases and bulk of the vacuum-packed blanket-after unpacking

(Pre-conditioned): 60°C-1 hr

Fig. 15 Rate of bulk recovery of vacuum-packed raised blanket (acrylic) after unpacking under the same condition in Fig. 12

Furthermore, reduction ratio from the side of volume and compression energy, storage-term and the recovering ability of bulk and creases of blanket after unpacking should be also considered.

4.8 Storage temperature of the vacuum-packed and it's influence

Table 6 and Fig. 13 show the recovering ability of bulk of unpacked blankets afetr long-term storage for 50-60 days at 20°C-65% RH environment.

We found that the longer storage-term becomes, the more the recovering term of bulk and crease of blanket takes in comparison with that of 7 days storage-term shown in table 4.

It means that to reduce the moisture content of fiber before packaging isn't always enough to get full recovering bulk and crease of unpacked blanket after long-term storage.

So we discussed the effect of storage temperature of the vacuum-packed blanket too. The recovering abilities of bulk of

Fig. 14 Rate of bulk recovery of the vacuum-packed raised blanket (wool) after unpacking under the different temperatures in storage

(Storage term): 45 days
 (Recovering condition): 20°C-65%
 (Pre-conditioned): 60°C-2 hr
 (Vacuum-packed pressure): -600 mmHg

Fig. 16 Rate of bulk recovery of the vacuum-packed-piled blanket (wool) after unpacking under the same condition in Fig. 12

Fig. 17 Rate of bulk recovery of the vacuum-packed piled (acrylic) blanket after unpacking under the same condition in Fig. 12

blankets after unpacking, which is influenced by the effect of storage temperature under long-term storage, are shown in Figs. 14–17. And creases of these blankets are also shown in Figs. 18–21.

As for the vacuum-packed blanket which was stored at the low temperature: $-2-0^{\circ}\text{C}$, it shows that the bulk thickness of blanket after unpacking recovers the native condition from the reduced bulk in a short time in spite of 45 days long-term storage in comparison with the storage temperature at 20°C . The raised-blanket illustrated in Fig. 12, of which recovering ability of bulk concerning about the time is better than that of the native blanket after unpacking.

This might cause as follows, the blanket before vacuum packaging was stored on the folded state anywhere for long-term storage and the bulk thickness had been already decreased only a little to the native state. So the effect of hygroscopicity by high moisture content of wool fiber made it recover to the real bulk thickness of blanket after unpacking.

On the contrary, crease of wool-blanket after unpacking disappeared in a short time without the effect of storage temperature. But crease of acrylic-blanket after unpacking didn't disappear in spite of recovering the reduced bulk to the native state with the passing time after unpacking at the storage temperature: 20°C . And crease of acrylic blanket at the low

The effect by storage temperature of blanket after vacuum packaging.

pre-conditioned at 60°C -2 hours
24 hours later after unpacking

storage	storage
at -2°C	20°C -65%
(after vacuum packaging)

Storage term:	45 days
Recovering condition:	20°C -65%
Vacuum-packed-pressure:	-600mmHg
Time after unpacking:	24 hr

Fig. 18 Creases of vacuum-packed raised blanket in wool after unpacking under different storage temperatures

The effect by storage temperature of blanket after vacuum packaging.

pre-conditioned at 60°C -1 hr
1 hour later after unpacking

storage	storage
at 20°C -65%	at -2°C
(after vacuum packaging)

However, time after unpacking: 1 hr

Fig. 19 Creases of the vacuum-packed raised acrylic blanket after unpacking under the same condition of Fig. 16

temperature storage: $-2-0^{\circ}\text{C}$, almost disappeared after unpacking.

The recovering ability of bulk and creases of wool-blanket, acrylic-blanket weren't affected by only the moisture content of fiber, but also with the storage temperature after vacuum packaging.

Therefore, it is recommendable to store the blanket at the low temperature: $-2-0^{\circ}\text{C}$.

5. Most Appropriate Vacuum Packaging Method of Home Furnishings (Case Study on Blankets)

However, time after unpacking: 1 hr

Fig. 20 Creases of the vacuum-packed piled wool blanket after unpacking under the same condition of Fig. 16

However, time after unpacking: 1 hr

Fig. 21 Creases of the vacuum-packed piled acrylic blanket after unpacking under the same condition of Fig. 16.

The experimental studies have shown that by means of careful packaging and regulating compression of wrapping and storage conditions, wool and acrylic blanket can practically recover the bulk to the native state in spite of a significant bulk reduction.

The most appropriate Vacuum Packaging Method consists of the following four processes, that is, in turn:

1) Packaging and wrapping materials:

To select compound layer-films having superior barrier ability, that is, to avoid moisture vapor transmission and leakage during the transportation and the storage.

(2) Pre-conditioning:

Reducing the moisture content of fiber with pre-conditioning should be done as rapidly as possible without influencing on the physical properties of fibers composing blanket articles.

(3) Setting of compression for vacuum packaging:

In order to set the most appropriate compression, bulk reduction-compression curve raw materials and fabric structure of

Table 7 The questionnaire result of the vacuum-packed blanket by unpacking after long-term: 6 months storage
(Term after unpacking): 20 days
(Recovery condition): 20°C-65%RH
(Storage term): 6 months

Blanket type	Feeling ○ ?×	Appearance (to creases)	Panelists (*-nocomment)
Piled blanket (acrylic)	7—○ 2—×	6—good 3—no good	9
Raised blanket (wool)	12—○	9—good 3—no good	12
Raised blanket (acrylic)	6—○ 2—×	2—good 8—no good	10 2*
Raised blanket (casimere)	11—○ 1—×	9—good 3—no good	12

*For feeling: ○—no problem, ?—doubtful, ×—problem

*For appearance: Being no problems to creases is “good”.
Being problems to creases is “no good”.

the blanket articles should be considered.

(4) Storage conditioning:

For storing at the low temperature the vacuum-packed blanket after vacuum packaging.

Recovering ability of bulk and creases of blanket after unpacking can be the most appropriate by means of appropriate selecting of raw materials and structure of the blanket articles.

6. Conclusion

The vacuum packaging of blanket has been investigated to reduce and recover the bulk of it. Following conclusions were obtained from results and considerations.

(1) The vacuum-packed blanket is effected by the moisture content of fiber and humidity inside package. Therefore, in order to reduce bulk of the blanket, it is necessary to regulate by pre-conditioning without an increase in the level of segmental mobility in fiber to reduce the moisture content of fiber. With heat drying at the temperature 58–60°C, acrylic blanket should be dried for 40 min and wool blanket for 100–120 min.

The compacting pressure should be determined by considering the reduction ratio and the recovering ability of bulk of the blanket after unpacking;

(2) In order to recover bulk of blanket to the native state within about 24 hr after 60 days or longer storage with the vacuum packaging blanket made of wool, the raised-blanket should be determined to set at the condition where vacuum pressure is set at below –450 mmHg, then reduction ratio becomes 1/3–1/3.5 of the native thickness, or pressure variation ratio by compression becomes below 0.272.

The piled-blanket should be determined to set the condition below –400 mmHg and reduction ratio becomes 1/6 or not any longer, and pressure variation ratio by compression becomes about 0.272.

Therefore, bulk of blanket will be expected to recover effectively to the native state.

(3) In order to recover bulk to the native state with less than 3 days after 60 days or longer storage of the vacuum packaging blanket made of acrylic material, the raised-blanket should be determined to be set at the condition where vacuum pressure is set below –450 mmHg, and reduction ratio becomes 1/3 of the native thickness or pressure variation ratio by compression

Table 8 Panelists' comments to the vacuum-packed blankets after unpacking

- (1) It can be very full of use by the usefulness, price line of blanket.
- (2) The vacuum-packed wool blanket has a property of good recovery (Perhaps, high recovering ability is due to wool raw materials).
- (3) The used-blanket is better than the unused-blanket in storage.
- (4) The factor of creases will be mainly due to the folding method of blanket.
- (5) It has totally no problems (In case of exportation, the blanket is pressed and banded with tape by the packaging maker. And so it has no problems for exportation at all. However, in case of Japanese demand, we'll need to hear distributors' opinions).
- (6) Acrylic blankets is not good at recovering ability, of creases. Especially the creases caused by folding remain on the knitting mayer acrylic-blanket.
- (7) We hope that the recovering ability of creases and bulk of blanket after unpacking, the vacuum-packed blanket can recover within 1–2 hours.
- (8) The vacuum-packed blanket is very useful for the transportation in short-term packaging.
- (9) The recovering ability of creases and bulk of blankets after unpacking will effect by the processing methods of blanket.
Polishing-processed blanket is apt to cause creases and not be easily to recover to the original state.

becomes below 0.272.

And the piled-blanket should be determined to be set at the condition where vacuum pressure below -400 mmHg and reduction ratio becomes $1/5$ – $1/6$ and pressure variation ratio by compression becomes 0.272.

Therefore, bulk of blanket will be expected to recover effectively to the native state.

(4) To recover effectively bulk and creases of blanket after unpacking under the most appropriate storage after vacuum packaging of the blanket. It is recommendable to store the blanket at the low temperature. Especially the acrylic blanket recovers its bulk thickness and creases quickly after unpacking.

However, the results of (2), (3) were obtained at the storage temperature: 20°C .

If the storage temperature of blanket is set at the low temperature, recovering ability of bulk and creases of blanket after unpacking show the best condition in spite of long-term storage.

7. Addition

The questionnaire result of the vacuum-packed blanket by unpacking after long-term storage.

In order to get appropriate storage condition for the recovering ability of unpacked blanket after long-term storage, we stored the vacuum-packed wool, acrylic blankets for a long-term practically and examined the recovering ability.

7.1 Long-term storage and storage condition

The storage term of vacuum-packed blanket was set to 6 months, because we supposed the case that we don't use the blanket for half a year from spring to autumn. The vacuum-packed was stored at the temperature condition (10 – 30°C) from April to September in Japan.

7.2 Compressing condition (for vacuum packaging)

The compression setting on the condition which have been already studied in Conclusion-6.

7.3 The evaluation of the vacuum-packed blanket after unpacking

The evaluation of blanket after unpacking was performed by the questionnaire survey of the blanket producer and the persons concerned. With the evaluation of it, the vacuum packed blanket was unpacked and was evaluated in front of the panelists.

And 20 days later, the feeling, the bulk and the creases of the

unpacked blankets were evaluated, and the comments to the vacuum-packed blankets were given by them.

7.4 Result of evaluation

The evaluation by the questionnaire results are shown in Table 7.

More than 80% of the panelists evaluated [O] to be good with the feeling of wool blanket. 70% of the panelists evaluated [O] to be good with the feeling of acrylic blanket. With the creases of blanket, more than 70% of them evaluated [good] to be no problem but 30% of them evaluated that [it remains creases].

As I mentioned above, the questionnaire survey shows that vacuum-packed wool blanket is expected to recover from its creases and bulk in a short time of 24 hours by unpacking after 6 months storage at 10 – 30°C .

On the contrary, vacuum-packed acrylic blanket has some problems in crease recovery after unpacking. Panelists' comments to the vacuum-packed blanket were itemized in Table 8. From comments in Table 8, you will be able to expect the same evaluation with Conclusion-6.

8. Postscript

On this studies, we thanks for the following companies which were willing to supply many kinds of blankets to us and to cooperate with the side of packaging technology; KAMA-KO woolen textile, KOYO merchandise, TOA textile, TONAI Woolen Textile Co., Ltd. and DAIFUKU Co., Ltd. Furthermore, we deeply thanks for members of Home Furnishing Technology Organization of Osaka who were willing to cooperate with questionnaire survey.

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